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Sugar Pine Utilization: A 30-Year Transition

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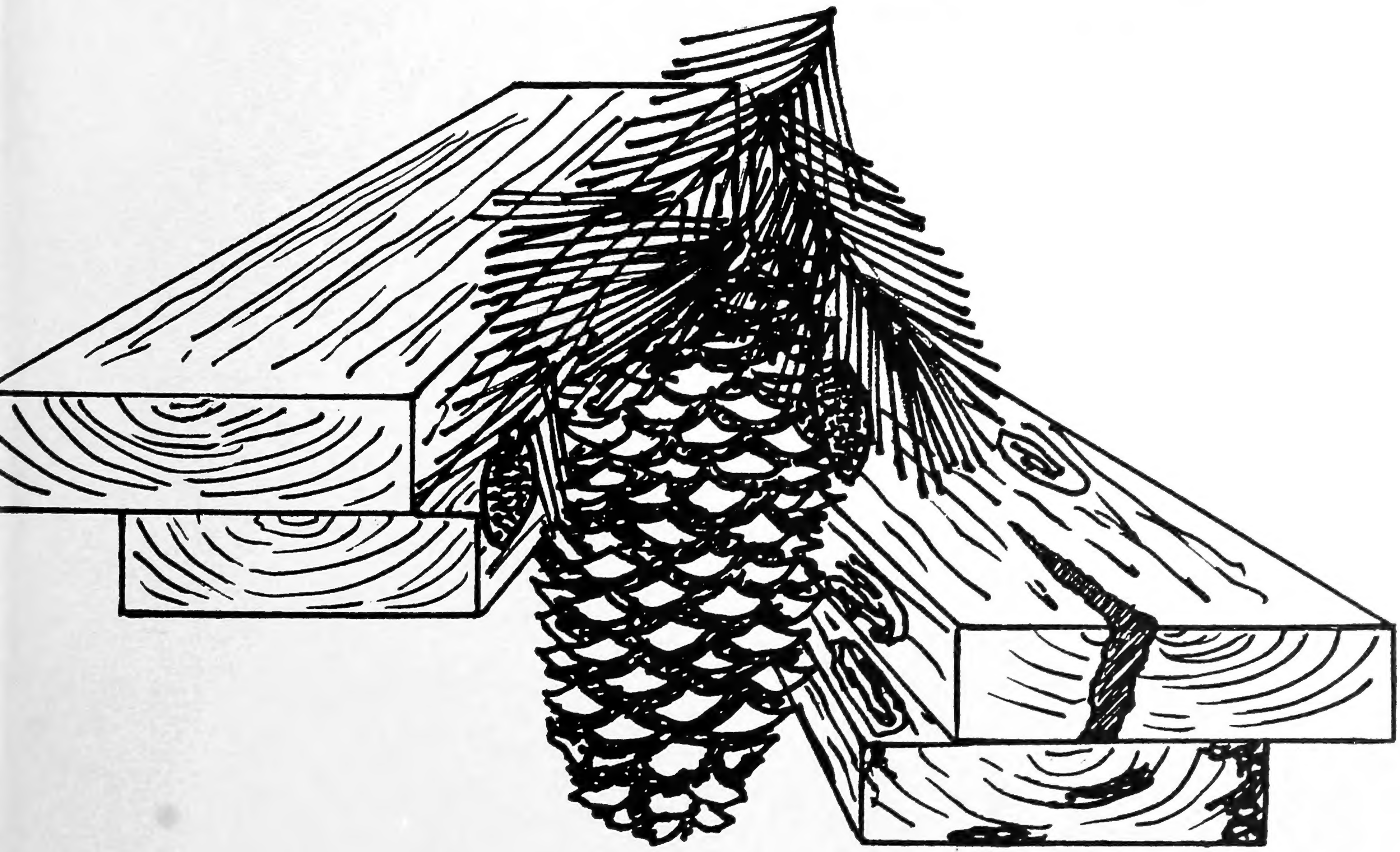

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Abstract

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Utilization standards and measurement systems have changed since the first lumber recovery study was conducted on sugar pine in 1957. These changes prompted a new study to provide new information on lumber volume and value recovery and a comparison to older studies. Lumber volume and value recovery are presented for the recent study on a board- and cubic-foot bases. Comparison to older studies showed that both volume and value increased over time because of improvements in technology, quality control methods, drying techniques; increased premiums for high grade clear material; and scarcity of the high-grade resource.

Keywords: Sugar pine, *Pinus lambertiana*, lumber, California, board feet, cubic feet.

Summary

Utilization standards and measurement systems have changed since the first lumber recovery study on sugar pine was conducted in 1957. Minimum log size has decreased from 10 inches and 10 feet to 6 inches and 8 feet. Minimum specification for cull logs under the Scribner system has changed from 33-1/3-percent sound to 25-percent sound. Measurement systems are progressing toward cubic log scale and cubic lumber volume for quality control. These changes prompted us to reevaluate the existing data on product recovery from sugar pine, and in 1984 a new study was conducted. The results of this study are presented here in both board-foot and cubic measurement units.

The comparison of the three studies showed that they are very similar with the volume and value increasing over time. Increases in volume are caused by changes in technology, improved quality control efforts (that increase sawing accuracy and decrease variation around target sizes), and improved drying techniques. Increases in value are caused by significantly higher premiums for high-grade lumber, better quality control of drying processes and conditions, and, to some extent, scarcity of the high-grade resource.

Frost cracks were a significant indicator of shake, which resulted in loss in lumber value. Further investigation in this area is needed to confirm that frost cracks should be considered a primary grading defect, thereby reducing the log grade to grade 5 to better estimate its true value.

Contents

Introduction

Sugar pine (*Pinus lambertiana* Dougl.) is one of the most valuable softwood species in the Western United States. It is found from northern Oregon to Baja California, and is concentrated in southern Oregon and northern California. It represents 7 percent of the commercial softwood timber volume and 7 percent of the growing stock in California (Colclasure and others 1986a, 1986b; Hiserote 1986; Lloyd and others 1986a, 1986b), and its average stumpage value has been nearly double that of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) for the last 10 years (Warren 1988). Sugar pine is a preferred species for paneling, cabinetry, and moulding stock because of its uniform appearance, workability, dimensional stability, and painting and finishing characteristics. The major lumber items produced are 4/4 to 12/4 Selects, 5/4 and thicker Factory grades, and 4/4 Commons.

The last published lumber recovery information is based on a mill recovery study conducted in 1957 (Wise 1964). Since then, changes have been made in utilization standards, measurement systems, and manufacturing and marketing; and to some extent, the resource itself has changed. Updated information is therefore needed by resource managers, timber appraisers, and mill owners.

The Timber Quality Research project at the USDA Forest Service Pacific Northwest Research Station, Portland, Oregon, in cooperation with the Pacific Southwest Region and the forest products industry, recently completed a study of old-growth sugar pine in the central Sierra Nevada region of California. This paper reports the results of that study conducted in Marysville, California, in 1984, along with a comparison of these results with the original study from 1957 and with a 1971 study, conducted by the Timber Quality Research project in cooperation with the Pacific Northwest Region and the forest products industry in Medford, Oregon.

Objectives

The two objectives of this paper are (1) to provide estimates of lumber volume, grade, and value recovery by log diameter and log grade for sugar pine that can be used for timber appraisals, inventory planning, or monitoring production decisions; and (2) to compare and contrast lumber recovery among the three mill studies conducted over 30 years and examine the reasons for some of the apparent changes.

Background

The 1957 Study, Standard, California

Sample—Study logs were selected from the mill pond, as described by Wise (1964), to provide a satisfactory sample within a good range of size classes and each log grade except grade 4. There were not sufficient grade 4 logs available to obtain a satisfactory sample. The same approximate relationship of butt logs to total number of logs within a log grade derived from the timber stand quality cruises was maintained in selecting the log sample.

Logs came from the Stanislaus National Forest and adjacent company lands (fig. 1). Minimum log size was 10 inches in diameter and 10 feet long. Merchantability standards were 33-1/3-percent sound. Eighty-four percent of the logs were 16 feet long, only 3 percent were longer than 16 feet, and 13 percent were shorter than 16 feet. Table 1 shows the sample by diameter and grade for each study.

Grading and scaling—The visible surface and end characteristics of each log were diagrammed in the pond or on the bull chain. Logs were graded "using the Region 5 Westside pine log grade specifications and from the diagram forms using Region 6 ponderosa pine log grade specifications. Subsequently, each log was graded from the diagram forms using the Improved Log Grade Specifications for Ponderosa Pine and Sugar Pine" (Wise 1964).

Figure 1—Location of sample areas and mill sites for all three sugar pine recovery studies.

Table 1—Distribution of sugar pine logs by diameter class, log grade and study

	Number of logs by study and log grade											
	Standard				Medford				Marysville			
Diameter	1	2	3	5	1	2	3	5	1	2	3	5
Inches												
6-9								5				15
10-13		1	1	1				25				20
14-17			2	10		1	1	32			2	32
18-21		5	3	14		4	1	54				42
22-25		3	7	15	4	1	6	47	1	1	17	35
26-29		3	7	10	4	2	10	47	2	4	16	27
30-33	2	7	9	9	8	11	14	27	4	9	14	38
34-37	4	12	10	7	5	9	13	13	5	7	14	32
38-41	3	9	19	9	20	4	4	5	11	5	9	18
42-45	4	15	19	7	6	5	3	2	2	6	11	10
46-49	7	6	17	5	8	2	2		1	4	5	4
50-53	7	5	15	3	3				1		2	2
54-57	7	5	14	3						2	1	1
58-61	2	9	7									
62-65	5	2										
Total	41	82	130	91	78	39	54	257	27	38	91	276

The information in the final report was based on the improved pine log grade specifications. After they were bucked to sawmill length, logs were scaled by a Forest Service check scaler, using Scribner scale rules found in the National Forest Log Scaling Handbook in effect at the time.

Sawing, drying, and tallying—

> "The sawmill included two band headrigs, a one-pass resaw, two edgers, and two trimmers. All logs with a shop and better face were taper sawn. The practice of sawing to produce the maximum lumber recovery and the highest values in standard select, shop and common lumber grades was followed during the study without regard to special orders or items" (Wise 1964).
>
> "About one-sixth of the shop and better grades of sugar pine lumber was kiln dried. The rest of the shop and better and all of the common grades of sugar pine lumber were air dried" (Wise 1964).

All lumber was graded and tallied on the green chain and on the dry chain after drying. A rough-dry to surfaced-dry conversion factor was derived by surfacing a 25-percent sample of the lumber.

Two batch tests were run at different mills to verify the results. The average lumber sales value obtained in the batch tests was 1 percent more than the predicted lumber sales value from the mill study, and the average overrun was 2-1/2 percent more than the predicted.

The 1971 Study, Medford, Oregon

Sample—Trees were selected to obtain a full range of size and quality of sugar pine logs. The sample was selected from five sale areas adjacent to the mill. The areas were in the Rogue River and Siskiyou National Forests, and the Medford District of the Bureau of Land Management (fig. 1). Sixty-six trees were selected across a range of diameters and grades of the butt log. Trees were felled and bucked according to industry standards. Logs were primarily 16 feet long (65 percent), 8 percent of the logs were longer than 16 feet and 27 percent shorter than 16 feet. Merchantability standards were 33-1/3-percent sound.

Grading and scaling—Logs were scaled in the millyard according to Scribner scale rules in the National Forest Log Scaling Handbook in effect at that time, and the Uniform Scaling Bureau rules (Northwest Log Rules Advisory Group 1969). The logs were graded by using Gaines (1962) grading rules on woods-length and mill-length segments. Logs were also graded by using modified grading rules which excluded knot indicators (Henley 1972). No grade 4 logs were found.

Sawing, drying, and tallying—The sawmill had a single-cut 7-foot band saw, a four-saw bull edger, a gang trimsaw, and a twin-band vertical line-bar resaw inside, and a single-band resaw on the green chain. Logs were sawn to obtain the optimum recovery from each log, with a representative product mix. Products were 4/4 Shops and Selects, 5/4 Shop, Moulding, and Selects, and 4/4 Commons. Lumber was tallied and graded on the green chain. A sample of lumber was dried, planed, and tallied and rough-green to surfaced-dry conversion factors were developed and applied to the green lumber grades and volumes.

The 1984 Study, Marysville, California

Sample—This study was conducted on timber from the central Sierra Nevada of California. The sample was made up of 85 old-growth sugar pine trees (180 years and older) and was selected from eight areas on the Tahoe and Plumas National Forests (fig. 1). The sample was selected to represent the range of size and grade that was available, *not* a typical "camp run" of logs. Individual trees were selected based on d.b.h. (diameter at breast height) and butt log grade. Trees were felled and bucked according to mill specifications.

Minimum log size was 6 inches in diameter and 10 feet long. Merchantability standards were 25-percent sound. The majority of the mill length logs were 16 feet long (74 percent), 2 percent were longer than 16 feet, and 24 percent were shorter than 16 feet.

Grading and scaling—Logs were graded in the standing tree by a Forest Service check cruiser using Gaines (1962) (same grades as the other studies, but applied while the trees were standing). Surface characteristics on all grade 1 and grade 2 logs were diagrammed. Logs were scaled in the log yard according to Scribner (USDA Forest Service 1977) and cubic rules[1] and according to Scribner rules on the mill deck after bucking. Cubic scale for mill-length logs was developed from the cubic scale and diagrams for the yard length logs. No grade 4 logs were found.

Because the tree sample for this study generated more grade 5 logs than were needed for a valid sample, the grade 5 logs from half the trees were dropped from the study. If the grade 5 log was part of a 32-foot log with a higher grade 16-foot log, the grade 5 log was left in the sample.

Sawing, drying, and tallying—The sawmill was a large log-cutting mill specializing in cutting for lumber grade. Primary breakdown for large logs was an 8-foot double-cut band saw. Small logs and cants expected to yield 3 Common and Better grade lumber were sawn on a 7-foot pony rig. A rotary-gang battery was used for sawing cants that were expected to yield 4 Common or worse lumber into nominal 2-inch dimension lumber. A four-saw bull edger and a trimsaw were used to edge and trim for both headrigs. A separate resaw located outside the main mill was used for splitting double thick Commons cut at the pony rig. The logs were sawn into 4/4 Commons, 4/4 and heavy 5/4 Selects, heavy 5/4 Shops and Moulding, and 8/4 Dimension. All lumber was kiln dried. Moulding and Better grades of lumber were tallied in the rough-dry condition. All other lumber was tallied after surfacing. All lumber was graded according to published grades (Western Wood Products Association 1981) under the supervision of a Western Wood Products Association grade inspector.

Target Sizes

The following tabulation shows the target thickness sizes for rough green lumber used by each mill:

Nominal thickness	1957	1971[2]	1984[2]
	- - - - - *Inches* - - - - - -		
4/4	1.03	0.95	0.996
5/4	1.43	1.41	1.47
6/4	1.69		1.69
8/4	2.06		1.69

[1] National Cubic Measurement Committee. 1978. The draft cubic log scaling handbook. Washington, DC: U.S. Department of Agriculture, Forest Service. 206 p. On file with: Timber Quality Research Project, Forestry Sciences Laboratory, Pacific Northwest Research Station, P.O. Box 3890, Portland, OR 97208-3890.

[2] Actual measurements.

Lumber Grade Groups and Prices

Lumber grades have been combined into groups (table 2) based on sales and pricing information developed for ponderosa pine (Warren 1988). The prices used to calculate log value in this paper are averages, however, for individual lumber grades for 1987 and were provided by the Pacific Southwest Region. The lumber was first priced by individual grades and then combined into grade groups for ease of presentation.

The price for Factory Select (table 2) is lower than the price for No. 1 Shop and No. 2 Shop, because the Factory Select price is based on 4/4 material and the Shop prices are a weighted average of 4/4 and 5/4 prices. Shop prices for 5/4 are usually several hundred dollars higher than for 4/4; the majority of the Shop is sawn into 5/4 lumber.

Data Available

The logs in each study were processed through the mill, and each piece of lumber was identified so that each board could be traced back to the original log. The data were summarized for each log. The only data available from the 1957 study are the published summary information by log diameter (Wise 1964). Data for the 1971 and 1984 studies are available for individual logs. All information in this paper is based on mill-length logs.

Analysis

The analysis is separated into four sections: lumber volume recovery, lumber value recovery, log value recovery, and comparison of studies. Major sources of variation that were analyzed are log diameter, log grade, and mill technology. Past studies (Fahey 1983, Willits and Fahey 1988) show that small-end diameter and transformations thereof are the appropriate independent variables. Models tested were:

$$\begin{aligned}\text{Volume or value} = \; & b_0 + b_1 D\,, \\ & b_0 + b_1 1/D\,, \\ & b_0 + b_1 D + b_2 1/D\,, \\ & b_0 + b_1 D + b_2 1/D^2, \text{ and} \\ & b_0 + b_1 D + b_2 1/D + b_3 1/D^2.\end{aligned}$$

Standard regression techniques were used, and the best model was chosen by combining past experience with statistical indicators such as the coefficient of determination (R^2) and standard error of the estimate. A common model was selected for each dependent variable for all log grades and then separate regression equations were estimated for each log grade. Covariance analysis was done to test for differences among slopes, and if no differences were found among slopes, the intercepts were tested. Tests for significance were done at the 0.05-percent probability level.

Lumber Volume Recovery

Lumber volume recovery can be expressed in three ways: cubic recovery percent (CR%), lumber recovery factor (LRF), and recovery ratio (see "Glossary" for definitions). The CR% and LRF are based on cubic log volumes, and recovery ratio is based on Scribner log scale. Because no cubic log volumes were estimated in the 1957 and 1971 studies, CR% and LRF will only be estimated for the 1984 study. Even though statistical differences were found among log grades for recovery ratio, a combined curve was also estimated for practical use.

Lumber Value Recovery

Dollars per thousand board feet of lumber tally ($/MLT) is an indicator of average lumber value for individual logs. It is found by multiplying the percentage volume in each grade

Table 2—Lumber grade groups, lumber grades, and prices used for estimating average lumber value and log value

Grade group	Grades included	Price used
		Dollars/MBF
Select	B and C Select	1500
Moulding	D Select, Moulding	1150
Shop	Factory Select	411
	No. 1 Shop	515
	No. 2 Shop	460
	No. 3 Shop	350
Common	2 Common	390
	No. 3 Common	236
	No. 2 and Better Dimension	236
Economy	Shop Out	130
	4 Common	126
	No. 3 Dimension	126
	Utility	126
	Economy	63
	5 Common	63

group by the appropriate price. Because \$/MLT is the average value of the lumber produced and does not include bias due to defect estimation, it is a good indicator of the inherent quality of the wood. It was used to compare the log grades through covariance analysis to determine if the log grades are separating logs into distinct value classes.

Recovery of lumber for each lumber grade is used to explain differences in average lumber values. Dependent variables are the percentages of the total lumber volume which is recovered in each of the five lumber grade groups. Regression estimates are made for four of the groups, and the fifth group (Economy) is found by subtracting the other estimates from 100 percent. Separate estimates of recovery in each of the five grade groups are made for each of the four log grades.

Log Value

Log value estimates combine the lumber volume recovery with the lumber value to reflect the average value of the log. Dependent variables can be expressed in two ways: dollars per hundred cubic feet of log scale (\$/CCF) or dollars per thousand board feet of net Scribner scale (\$/MNLS). These estimates do not include by-product values or production costs. Regression estimates were made for each log grade that was significantly different in the analysis of \$/MLT.

Comparisons

Data for individual logs were available for the 1984 and 1971 studies. Only summary data were available for the 1957 study; information in each 1-inch diameter class was weighted by the frequency of logs to estimate regression models. Recovery ratio, lumber value (\$/MLT), lumber grade recovery, and log value (\$/MNLS) were used as dependent variables for each study. Comparisons were done graphically, not statistically, because of differences in model forms among the three studies and lack of information to estimate variation in the 1957 study.

Results and Discussion

Results for lumber volume, lumber value, and log value are presented for the Marysville study first; then results for the other two studies are shown as the three studies are compared.

The 1984 Study, Marysville, California

Lumber volume recovery—Cubic recovery percent gives the most accurate representation of lumber-volume-to-log-volume relations because both volumes are measured in cubic feet (Fahey and Snellgrove 1982); therefore, CR% was used to compare volume recovery among log grades. The best model form (table 6) was chosen based on the r^2 and standard error. No statistically significant differences were found among log grades. The CR% can also be used to estimate the recovery of sawdust and chips. The CR% of rough green lumber increases with diameter until about 20 inches then levels off (fig. 2), and the percentage of sawdust remains fairly constant, but the percentage of chips declines from 50 percent of the log volume of a 6-inch log to only 15 percent of a 20-inch log.

Lumber recovery factor is the lumber volume in board feet divided by the log volume in cubic feet. No statistical difference was found among log grades. The LRF curve (fig. 3, appendix, table 6) is very similar to the CR% curve; it increases rapidly in the small diameters and levels off in the larger diameters. This corresponds with the efficiency of sawing round logs into rectangular boards.

Final models for recovery ratio were selected because of past experience and statistics (table 6). No significant statistical differences were found between log grades 1 and 2 or between log grades 3 and 5 (fig. 4). Differences between these lines may be caused by differing taper (the average taper for grade 1 and 2 logs was 0.4 inch/foot and for the grade 3 and 5 logs it was 0.25 inch/foot), defect (average defect in the grade 1 and 2 logs was 6 percent; for the grade 3 and 5 logs, it was 4 percent), or diameter ranges. Recovery ratio is the most variable of the three estimates of lumber volume recovery. It is based on Scribner scale, which generally underestimates log volume by not recognizing taper and typically overestimates the effect of defect. The magnitude of the difference in variation between recovery ratio and CR% is shown in figure 5.

Lumber value recovery—Average lumber value, an indicator of the inherent wood quality, was used to test for differences among log grades. Statistically significant differences were found among all four log grades. As diameter increases, $/MLT increases for all log grades (fig. 6), but the value of the grade 2 logs less than 30 inches is lower than the grade 3 logs and the value of the grade 2 logs less than 26 inches is less than both the grade 3 and grade 5 logs. Final models are given in table 6, and the variation around the regression line for grade 5 logs is shown in figure 7.

Frost cracks—A close examination of grade 2 logs showed that of the 13 logs less than 30 inches in diameter, 5 had $/MLT less than $400. These five logs had frost cracks that were diagrammed in the standing tree, and the scale records show large deductions for shake.

An analysis of the lumber grade recovery showed that a large portion of the lumber recovered from these logs was graded as "Shop Out," which has a value of $130. This prompted us to analyze all the logs that showed frost cracks in the standing tree. Fifteen logs had visible cracks, one grade 1 log, four grade 2 logs, seven grade 3 logs, and three grade 5 logs.

Because of the small sample size of logs with frost cracks, the analysis of differences between logs with frost cracks and logs without frost cracks for each log grade should be considered exploratory. First, regression estimates of $/MLT by log grade for logs without frost cracks were developed. Then each of the logs with frost cracks was tested to determine

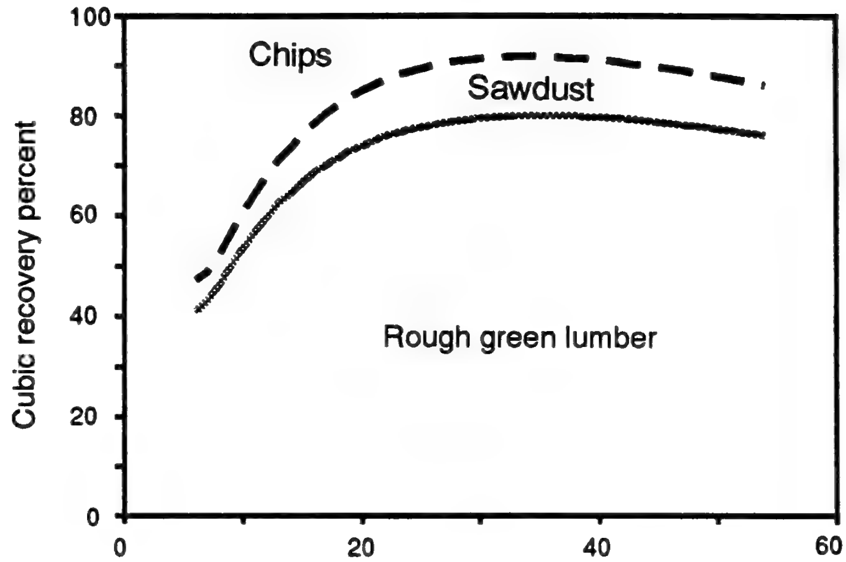

Figure 2—Cubic recovery percent for rough green lumber and rough green lumber and sawdust. Chip volume is found by subtracting rough green lumber and sawdust from 100 percent. No statistical differences were found among log grades, so one set of curves is presented.

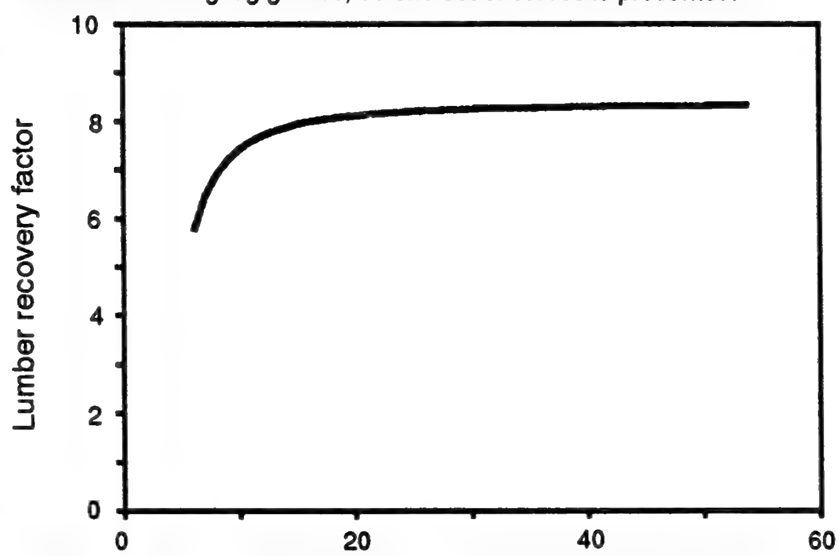

Figure 3—Lumber recovery factor is also presented for all log grades combined. Similar to CR%, it increases in the small-diameter range and then levels off because of changes in lumber sizes.

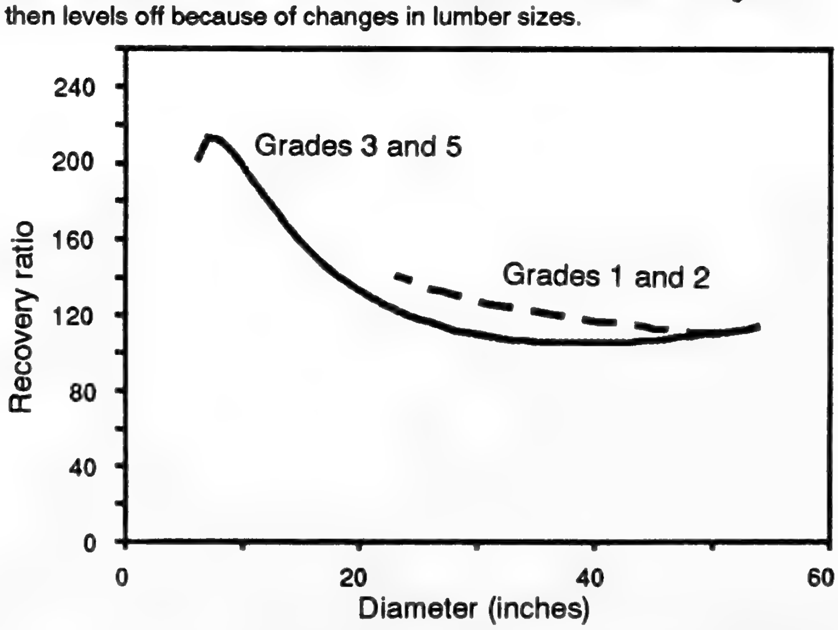

Figure 4—Statistical differences were found among log grades for recovery ratio. These differences may be caused by differences in taper and defect.

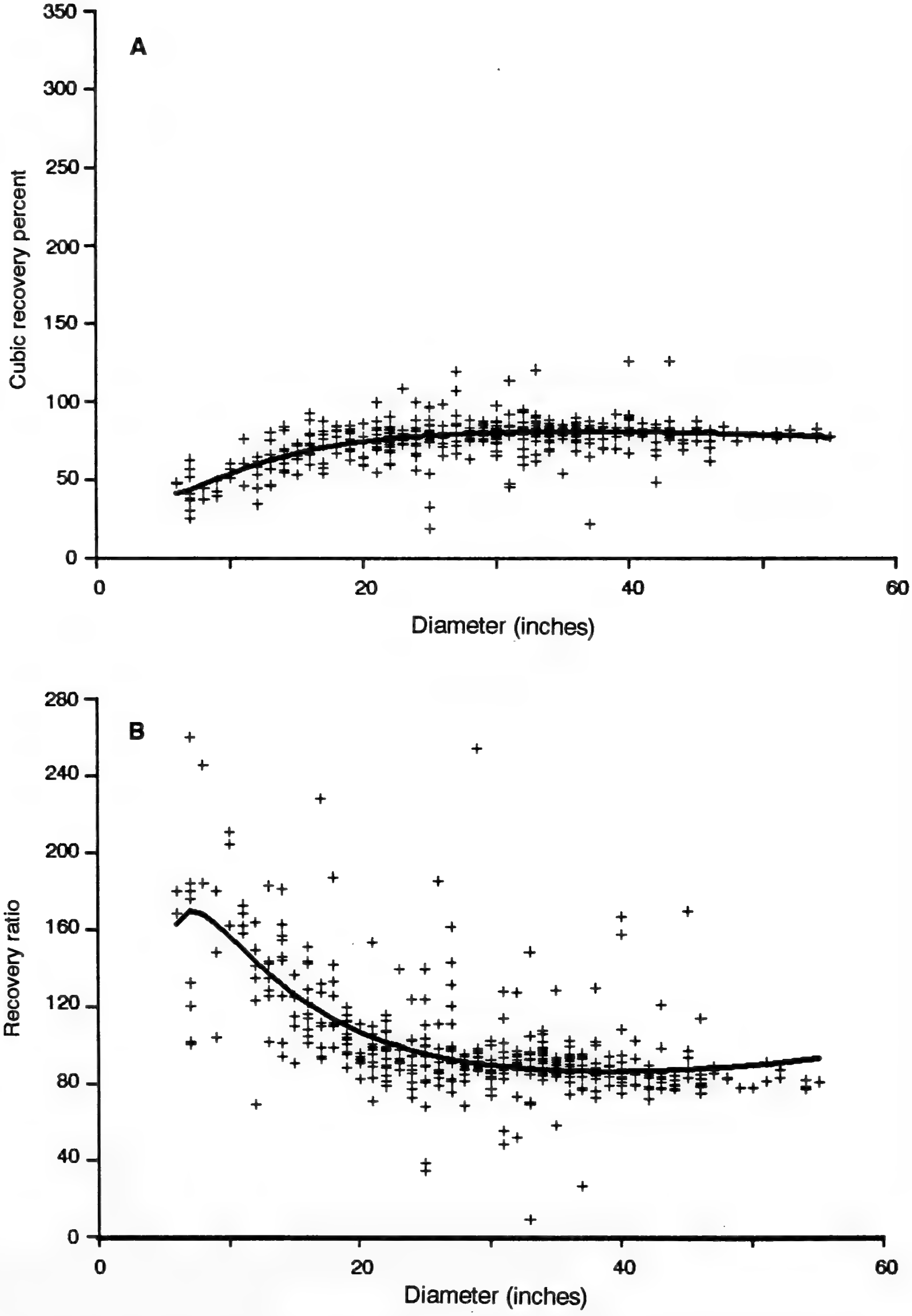

Figure 5—Examples of the variation around regression estimates are shown for CR% and recovery ratio. (A) Variation for CR% is small because of the use of cubic measurement for both logs and lumber volume. (B) Variation for recovery ratio is large because of inaccuracies in the Scribner scaling rules for estimating log volume and the use of nominal rather than actual sizes for board-foot lumber volume.

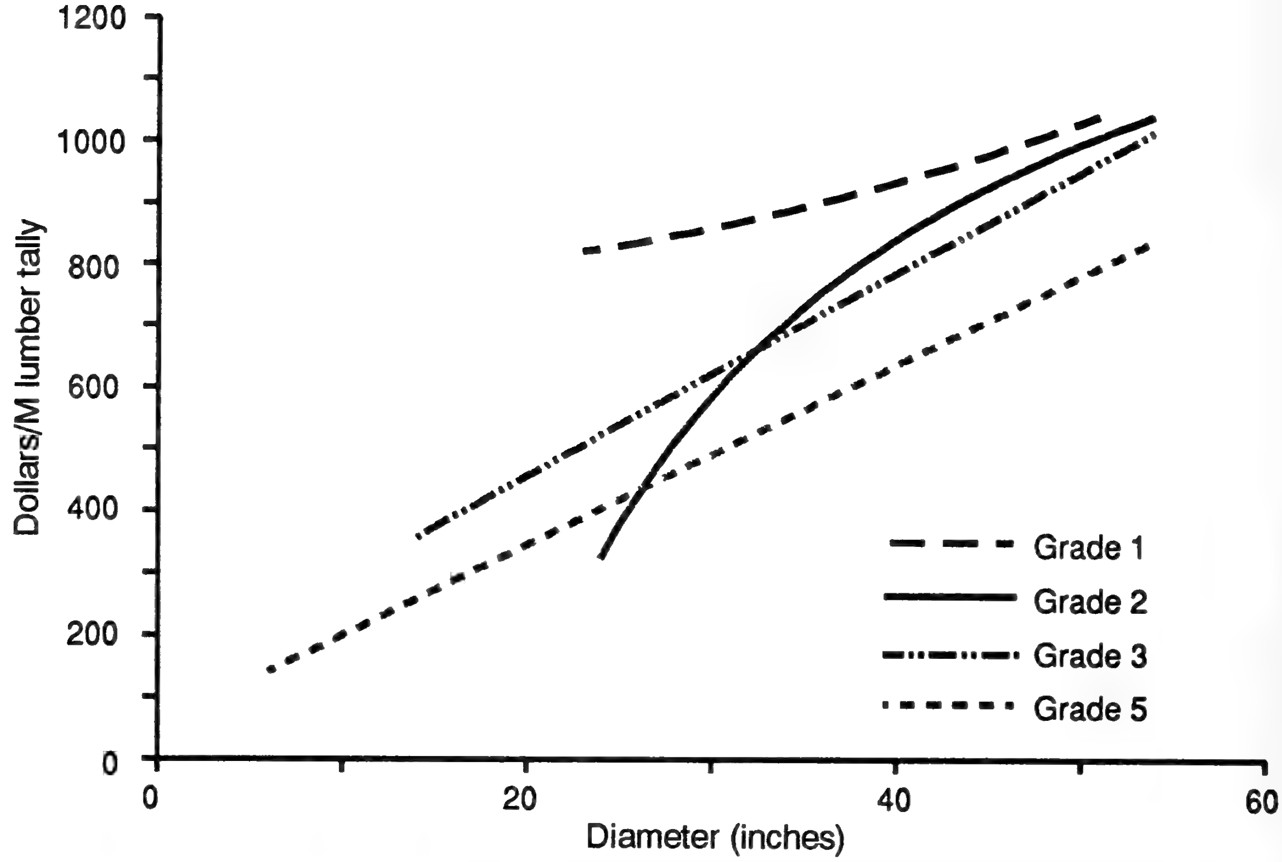

Figure 6—Average lumber value was different for all four log grades. All grades increased in value with diameter, but the Grade 2 logs were not always more valuable than the Grade 3 or Grade 5 logs. The value of the Grade 2 logs was affected by logs that had frost cracks.

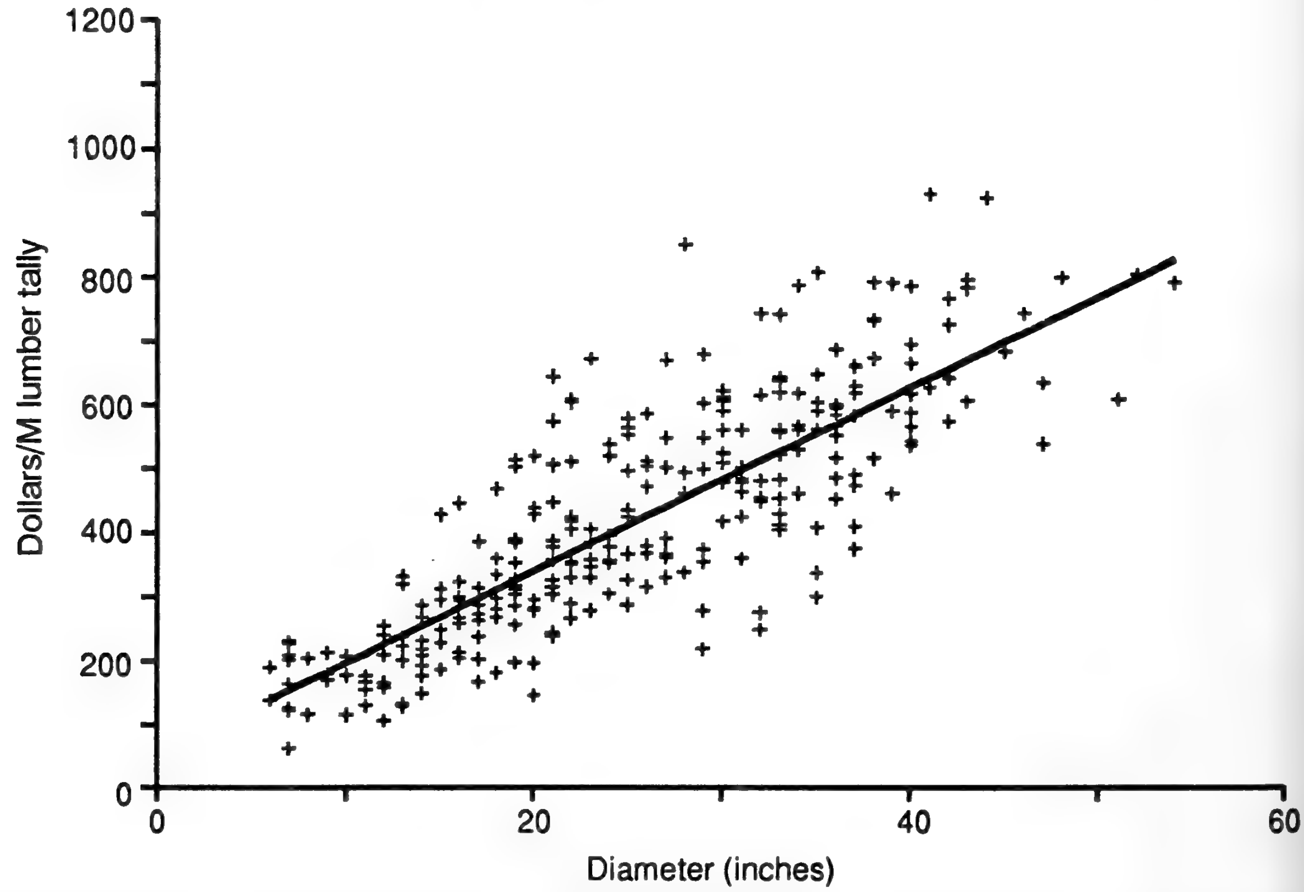

Figure 7—Variation around regression estimates for $/MLT is given for grade 5 logs only. It is typical of the variation for the other log grades.

if these estimates adequately predicted the volume and value recovery of logs with frost cracks. No significant differences were found in lumber volume recovery between the logs with and without frost cracks. Significant differences were found in value for the grade 2 and grade 3 logs; most logs with frost cracks fell below two standard deviation prediction intervals, and the average bias was -441 for grade 2 logs and -230 for grade 3 logs. The grade 5 logs with frost cracks were within the prediction intervals. Grade 1 logs were not analyzed because only one log had a frost crack. Table 3 shows the average values ($/MLT) for logs with frost crack and logs without frost cracks for a comparable diameter range.

Table 4 shows the average percentage recovery by lumber grade for logs with and without frost cracks. The high percentage of Shop Out and Economy lumber produced from the grade 2 logs with frost cracks indicated that an attempt was made to manufacture Shop or higher grade lumber from otherwise suitable wood, but that the lumber degraded to Shop Out and Economy as it dried. Review of the film taken at the planer showed that much of the lumber needed redrying. What had been shake in the tree was appearing as splits in the lumber that only became visible in the dried lumber. What could have been Moulding or Shop grade lumber was degraded because splits are not allowed in the clear cuttings on which Shop grades are based. The same trend occurs in the grade 3 logs with frost cracks. The grade 5 logs with frost cracks produced a slightly higher percentage of Select and Moulding lumber and considerably more Economy than the corresponding grade 5 logs without frost cracks; therefore, no value loss was detected in the grade 5 logs.

Although further research is needed in this area, this is a strong indication that visible frost cracks should be added to the grading criteria for sugar pine. When all the logs with frost cracks were compared to regression estimates for grade 5 logs, most were within the prediction interval, and the bias was reduced to -261 for grade 2 logs and -94 for grade 3 logs. We suggest that the net grading effect probably should be to lower the estimated value to that of a grade 5 log. If this grading change were made with this set of data, the net result in lumber value would be as shown in figure 8 (table 6). These estimates are also significantly different, statistically and they converge only at the upper end of the data for the grade 1 and 2 logs.

The relation between frost cracks and lumber value could not be evaluated on the earlier studies for two reasons: first, because the lumber was tallied before it was dried and a sample was used to estimate changes because of drying, it is impossible to trace the grade falldown to a specific log; second, there are no data left on the 1957 study to indicate whether the logs had frost cracks and the data on the 1971 study indicate that no logs with frost cracks occurred in the study.

Lumber grade recovery—Lumber grade recovery can also be used to show differences in average lumber value between log grades (fig. 9). The percentage of Select and Moulding increases as diameter increases and decreases as log grade changes from grade 1 to grade 5. The percentage of Common and Economy is about the same for grade 1 and grade 2 logs, but there is a difference in the percentage of Select and Moulding. Grade 3 logs produced slightly less Select and Economy but more Shop and Commons than did the grade 2 logs. The grade 5 logs produced almost no Select but more volume in Commons and Shops than did the grade 3 logs.

Log value—Log value is the combination of volume recovery and average lumber value. No tests were made among log grades because all four grades had significantly different $/MLT. The $/MNLS for both original log grades and the grades modified for frost cracks are

Table 3—Average lumber value ($/MLT) for comparison of logs with frost cracks to logs without frost cracks

Grade	Logs without frost cracks Number	Logs without frost cracks $/MLT	Logs with frost cracks Number	Logs with frost cracks $/MLT	Diameter range
2	13	711	5	243	24-36
3	22	606	7	345	22-28
5	91	376	3	404	17-26

Table 4—Percentage volume by lumber grade for logs with and without frost cracks

Grade	Logs without frost cracks					Logs with frost cracks				
	Select	Shop	Common	Econ	Shop Out	Select	Shop	Common	Econ	Shop Out
	Percent									
2	46	29	8	15	2	5	26	3	36	29
3	33	34	14	16	3	9	45	5	27	13
5	8	45	31	13	3	15	39	14	30	3

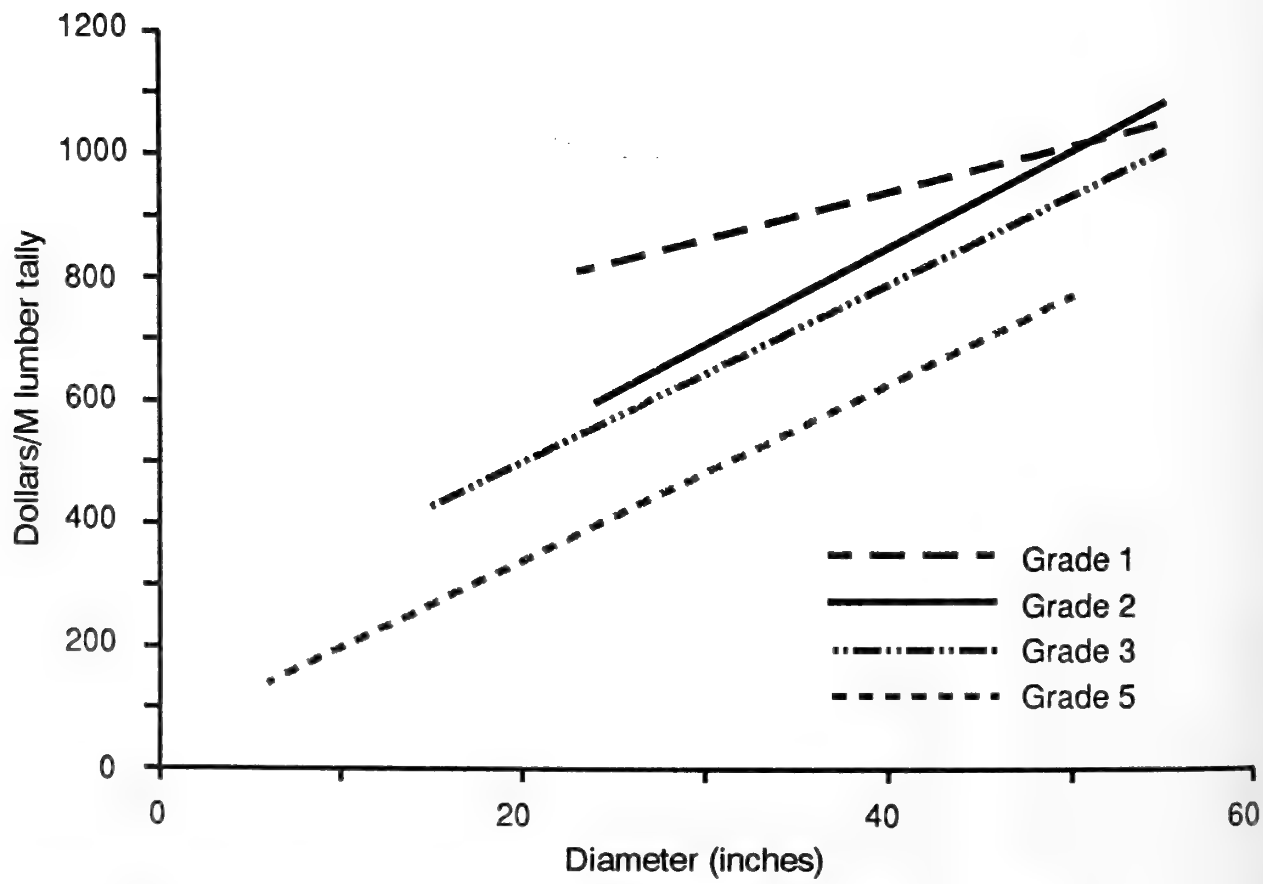

Figure 8—Average lumber value after logs with frost cracks were graded as grade 5. All grades are still different, but grade 2 logs are now consistently more valuable than grade 3 or grade 5 logs.

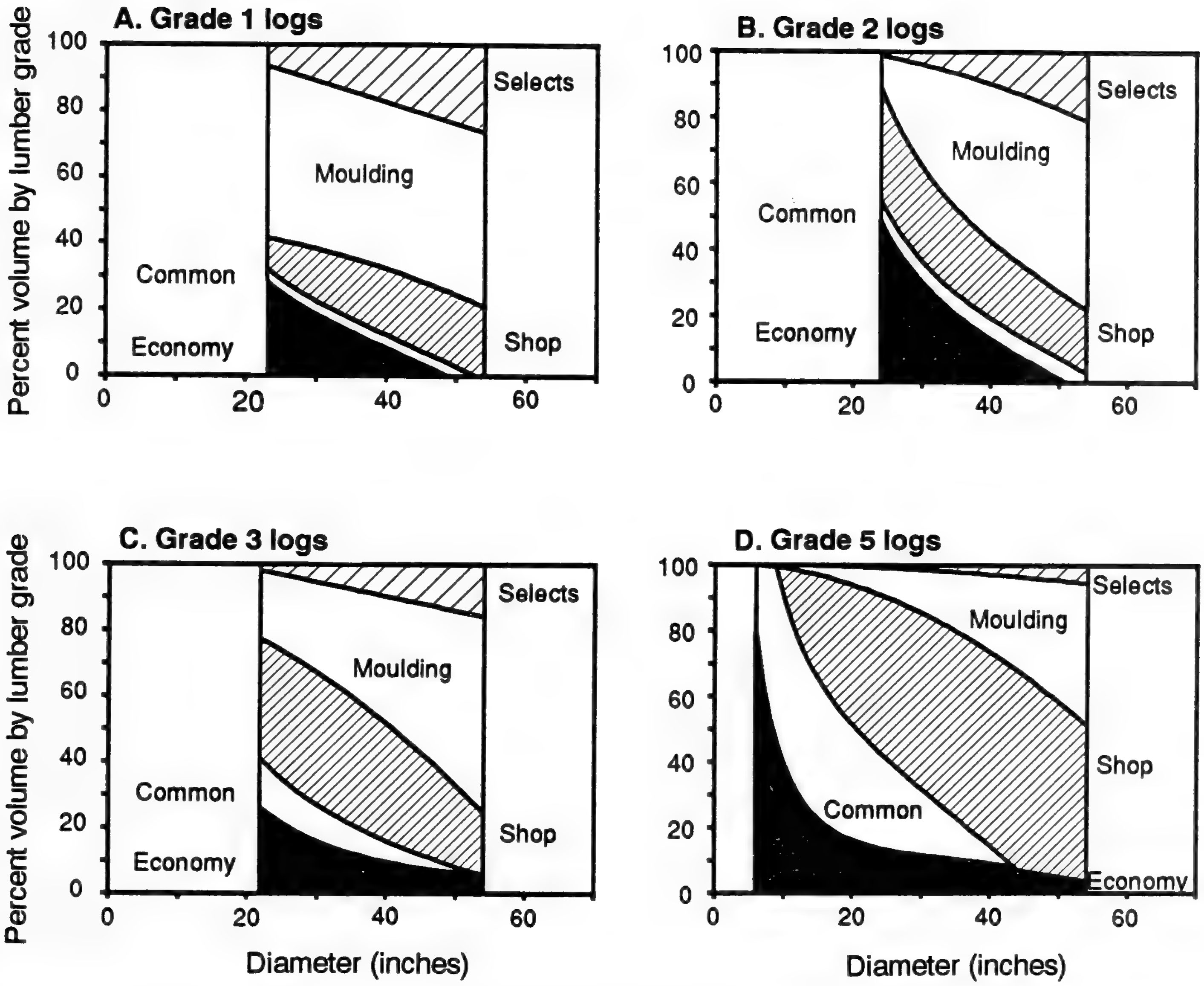

Figure 9—Percentage volume by lumber grade groups differs by diameter and log grade. These graphs are based on the original log grade before adjusting for frost cracks. The percentage of Selects and Moulding increases with log diameter and decreases with log grade. The high percentage of Economy lumber in grade 2 logs is because of frost cracks and associated shake, which produces splits in the dried lumber and degrades the lumber from Shop and Moulding to Shop Out and Economy.

shown in figure 10 (table 6). An example of the variation around the regression estimate for grade 5 logs is shown in figure 11. The higher log grades also had higher values that increased over diameter. The frost crack logs produced the same anomalies in \$/MNLS as they did in the \$/MLT analysis, but the modified grading also eliminated the crossing of the estimates for the smaller diameter logs.

Comparison

Since the study results became available, there has been much discussion about the adequacy of the sample, the accuracy of the grading, the efficiency of the mill, and the interpretation of the results. To address these concerns, we will present the following comparison or contrast of three mill studies with different sample locations, mills, and log-grading conditions. Although all the studies were conducted under different circumstances, the intent of all was the same: to collect enough information on each log in the sample to make a reliable prediction of the volume and value of lumber that can be produced from similar-sized logs for a given log grade. This comparison will include recovery ratio, \$/MLT, percentage of volume by lumber grade, and \$/MNLS, even though the net Scribner scales are not identical.

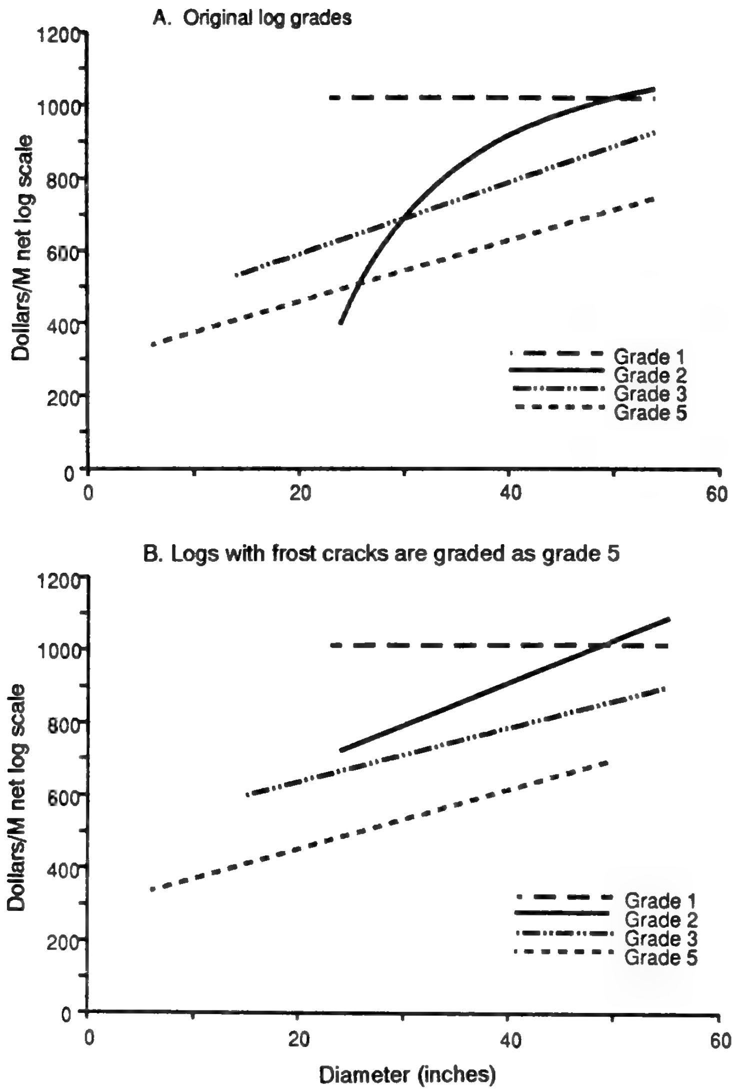

Figure 10—Average log value was different for all log grades. The effect of frost crack logs on the log value of the Grade 2 logs is similar to the effect on average lumber value.

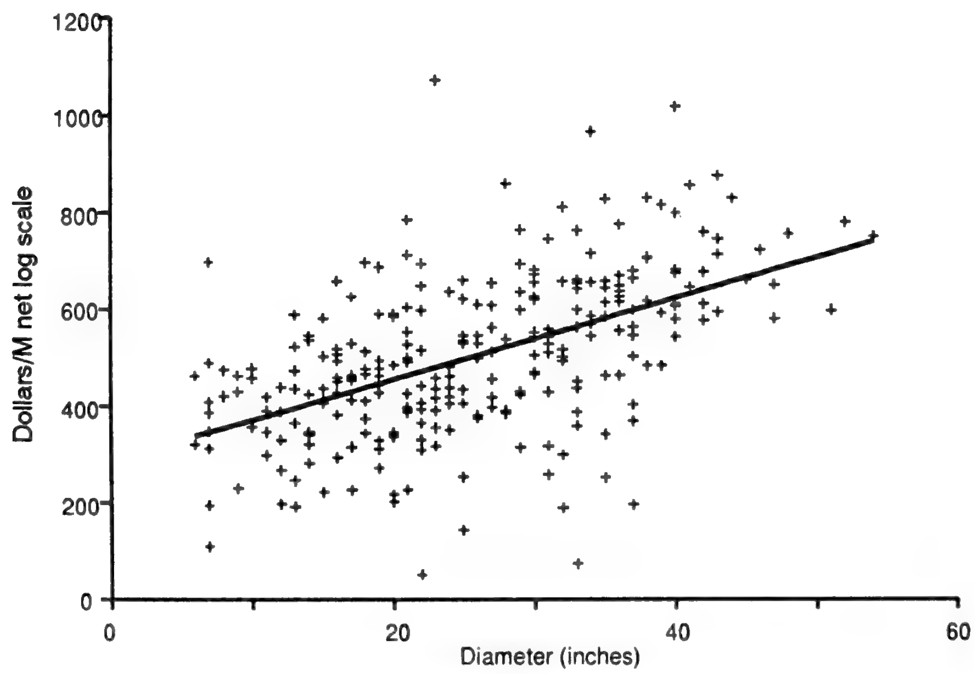

Figure 11—Variation around regression estimates for $/MNLS is also given for grade 5 logs. Variation was greater for $/MNLS than for $/MLT because $/MNLS is based on Scribner net scale.

Recovery ratio—Recovery ratios for each of the three mill studies are shown in figure 12. Given the variation associated with estimates of recovery ratio, the 1957 study and the 1971 study are not different. The 1984 study produced higher recovery for all logs, especially in the logs less than 25 inches in diameter. There are several reasons for this; first, because the mill in the 1984 study routinely processed small logs (the 1957 study had only three logs with a small-end diameter less than 15 inches, and the smallest log diameter in the 1971 study was 8 inches), it had a separate headrig that was designed to saw smaller logs. Other causes are technological improvements, such as thinner sawkerfs; quality control efforts in the mill that increased sawing accuracy; decreased variation around target sizes; and improved drying techniques. Lumber production also differed across studies. In the 1984 study, 90 percent of the lumber from logs less than 12 inches was 2-inch dimension lumber. Two-inch dimension lumber produces a high recovery ratio because it is tallied as 8/4 but cut to the same thickness (1.69 inches) as heavy 6/4; therefore, the actual cubic volume recovered is the same, but the board-foot volume is much higher for 2-inch lumber. In other words, the actual volume of lumber and number of boards would be the same for either 8/4 or 6/4, but the tally is 33 percent higher for the nominal 8/4 dimension. The mill in the 1984 study also produced a higher percentage of Moulding and lower percentage of Select from the portion of the log that can produce Moulding and Better lumber. Selects can be edged and trimmed to specified widths or cut random width, and Moulding is cut random width; for example, a partial slab that would yield an 8-inch Select may yield a 9- or 10-inch width of Moulding with some wane. Production of more Moulding, therefore, also increased the recovery ratio. The production of 2-inch dimension lumber and the choice between Moulding and Selects were driven by market conditions in effect during the study.

Value—The information presented in these comparisons is based on the modified grades, those using frost crack as a grading criteria, because we feel this is the best classification of logs by value. Diagrams of the logs in the 1971 study showed no recorded frost cracks, so the original grades were used. No diagrams or other notations are available for the Standard study, therefore, the information is based on the published grades.

Lumber value—In all cases, the lumber value of the 1957 study is below that of the 1971 and 1984 studies (fig. 13) for each log grade. The 1971 and 1984 studies are about equal but have small differences in slope of the lines. Average lumber values for the 1984 study have a steeper slope for log grades 2, 3, and 5. One reason may be that the 1984 mill recovered a higher percentage of Moulding and Better lumber from the larger diameter logs. Another may be that the earlier studies produced higher percentages of Factory Select: 9 percent in 1957 versus 1 percent in 1984. Because the production of Factory Select in general has decreased and the price is based on less than 1 percent of the total sugar pine market, it may not be an adequate reflection of the value of the material produced in the 1957 study. In 1987, the price of Factory Select was only 36 percent of the price of Moulding, but in 1963 the Factory Select price was 75 percent of the price of Moulding.

Table 5 gives the percentage by lumber grade for a 40-inch diameter log for each grade and mill. In general, the 1984 study produced a lower percentage of Select and a lower percentage of Shop but higher percentages of Moulding. The percentage of Shop lumber recovered from the grade 5 logs remained fairly constant, but the percentage in Economy lumber was greatly reduced. Changes in drying technology, in the care and

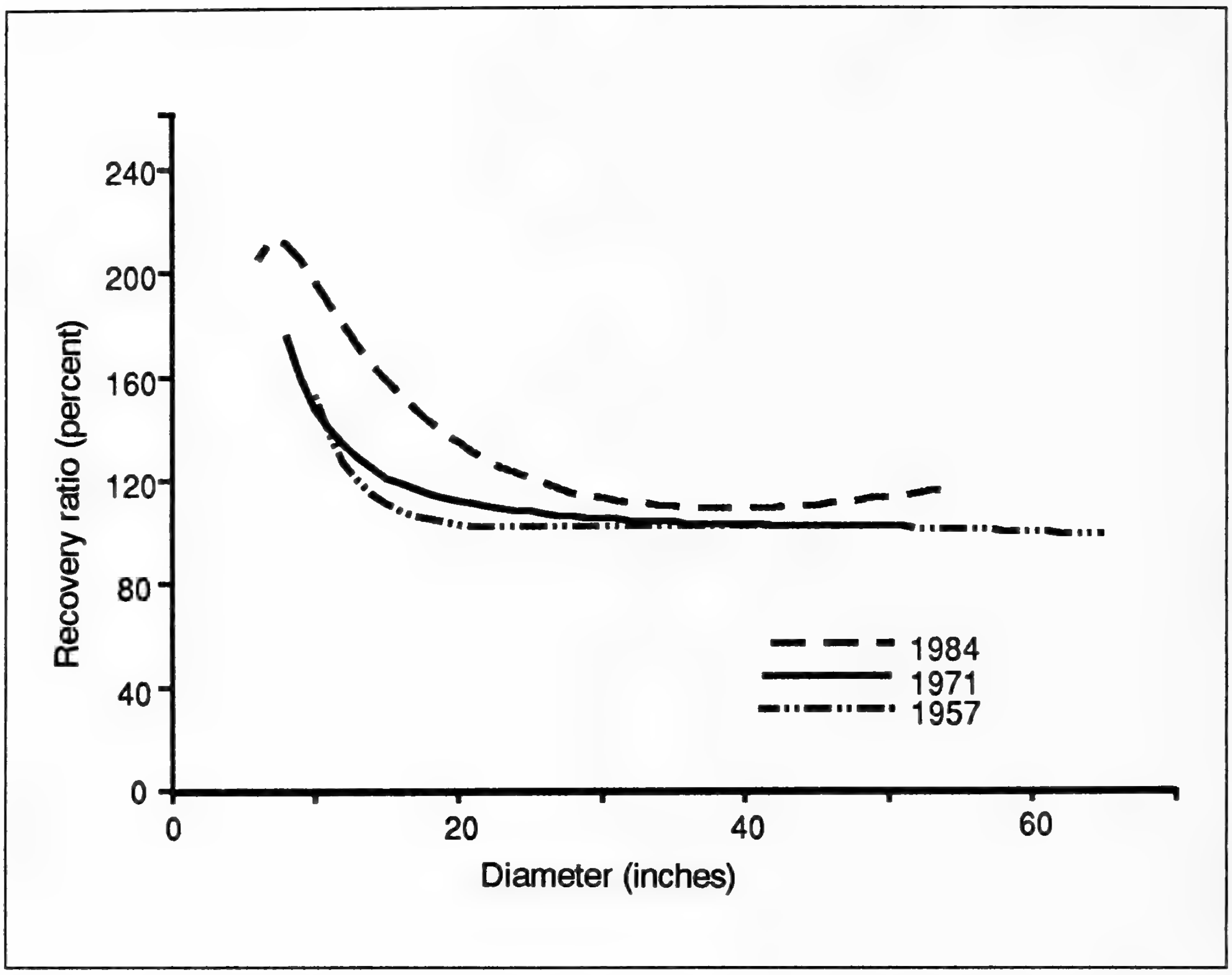

Figure 12—Recovery ratos for the three mills are very similar. The 1984 study had a higher recovery ratio in small logs because of more efficient milling, quality control efforts, and the production of 2-inch dimension lumber.

Table 5—Estimated percentage volume by lumber grade for a 40-inch diameter log for each log grade and each mill study

Lumber	Grade 1			Grade 2			Grade 3			Grade 5		
grade	1957	1971	1984	1957	1971	1984	1957	1971	1984	1957	1971	1984
Select	28	37	16	21	27	10	7	15	9	2	5	3
Moulding	29	27	52	22	24	50	10	18	39	4	11	24
Shop	28	23	20	41	31	24	60	46	36	62	58	65
Common	2	7	4	6	10	7	8	12	6	9	12	3

handling of lumber, and in the market for Economy lumber were related to the reduction in percentage of low-grade lumber.

Log value—Dollars per thousand net Scribner log scale is a combination of the recovery ratio and the average lumber value. Increases in recovery ratio and differences in lumber grade recovery produce higher estimates of \$/MNLS as time passes (fig. 14). The 1984 study produced the highest \$/MNLS with the 1971 study next and the 1957 study the lowest.

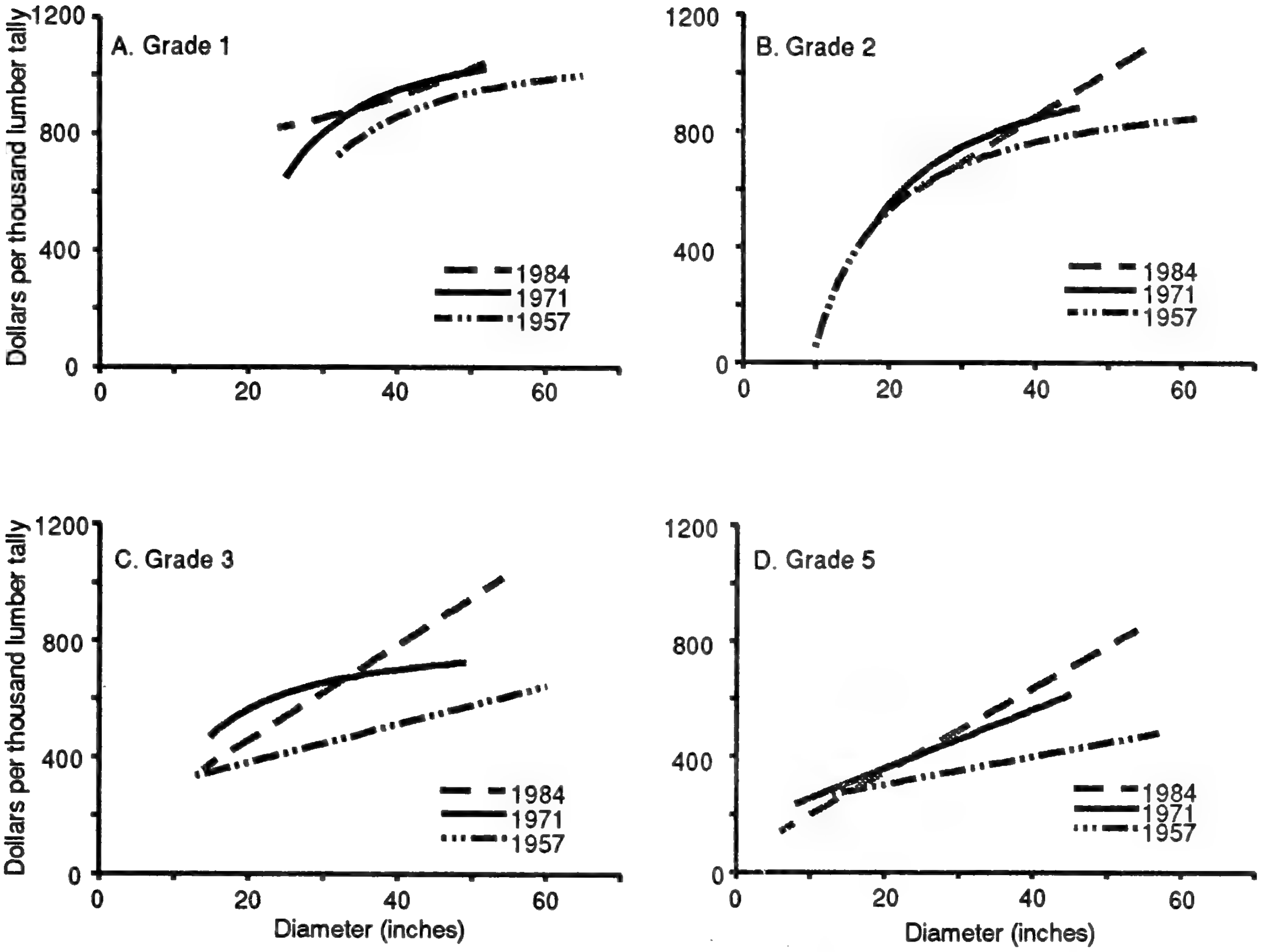

Figure 13—Dollars per thousand lumber tally for each study is presented for visual comparison only. The trend for all four log grades is similar, in general the more recent the study, the higher the average lumber value. This may be caused by better drying conditions, scarcity of the resource, or different marketing conditions.

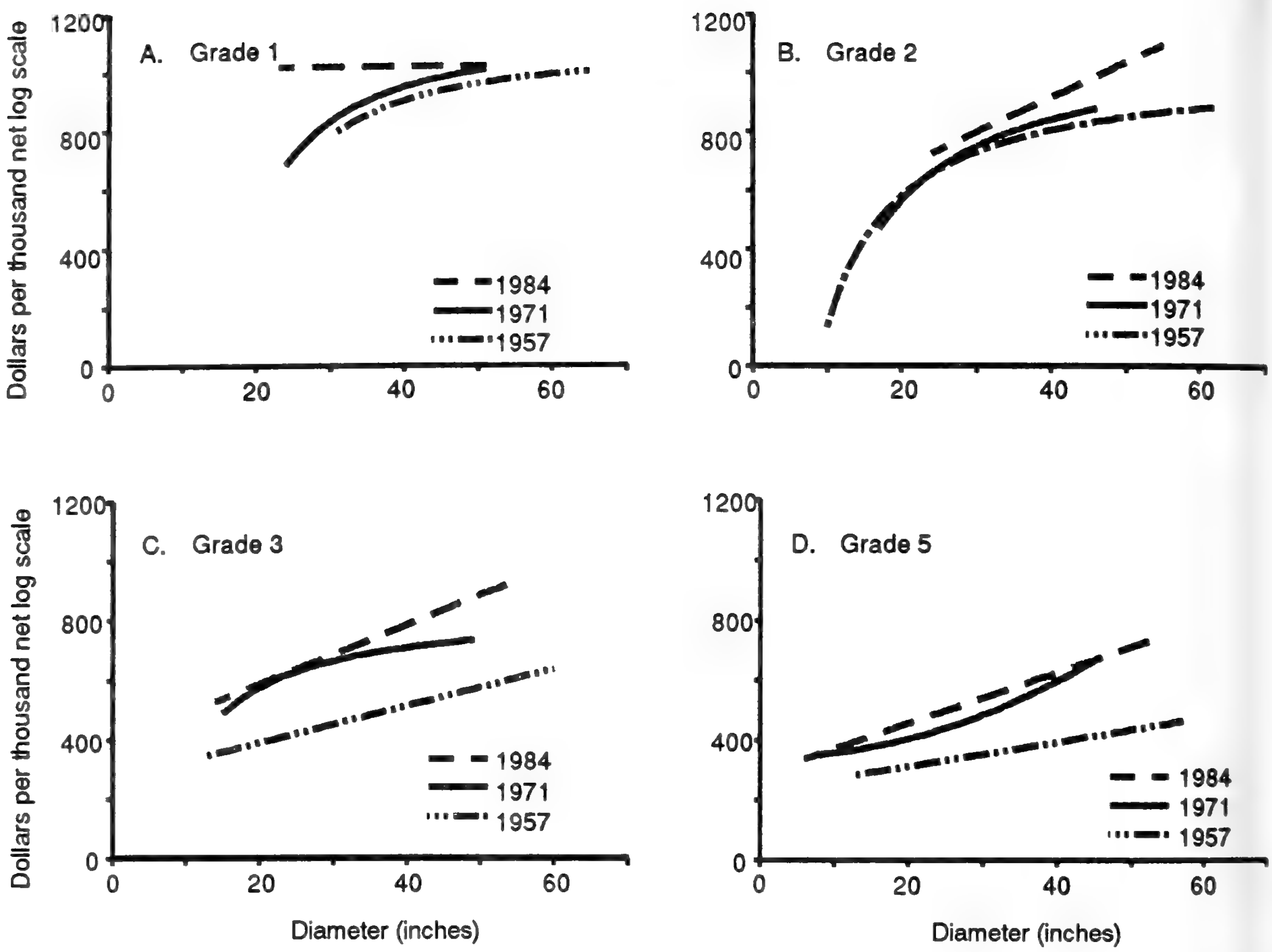

Figure 14—Average log value differed by log grade, but the same general trend applies, the more recent the study the higher the value.

Glossary

Cubic recovery percent (CR%)—The cubic feet of lumber produced from a cubic foot of log input. Log volume can be expressed as a percentage of the gross, net, or product cubic scale. Cubic recovery percent can be based on surfaced-dry as well as rough green lumber.

Dollars per hundred cubic feet of log scale ($/CCF)—The total value of the lumber produced from a log divided by the cubic scale of the log. Cubic scale volume may be gross, net, or product.

Dollars per thousand board feet lumber tally ($/MLT)—The average value of the lumber produced based on the lumber produced and the pricing structure used in this paper.

Frost crack—Open or closed scars presumably caused by freezing; a radial split of wood and bark which seems to be an extension of shake from within the bole.

Lumber recovery factor (LRF)—The board feet of lumber produced from a cubic foot of log input. As with cubic recovery percent, log input volume can be gross, net, or product cubic scale.

Recovery ratio (overrun)—The board feet of lumber produced from a board foot of net log scale and expressed as a percentage. In some cases, overrun and recovery ratio are used interchangeably. Technically, overrun is the board feet of lumber minus the net log scale, divided by the net log scale and expressed as a percentage, or the recovery ratio minus 100.

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Appendix

Table 6—Equations and statistics for estimates of volume recovery, 1984 study

Dependent variable and mill	Equation	R^2	$S_{y.x}$
CR% of rough green lumber	126.4-0.6*D-928.5/D+2637.2/D^2	0.32	15.4
CR% of lumber and sawdust	152-0.8*D-1178.8/D+3487.5/D^2	.32	15.4
LRF	9.16-0.02*D-140.0/D^2	.08	15.9
Recovery ratio:			
Grade 1 and 2	123.94-0.38*D+13927/D^2	.07	22.3
Grade 3 and 5	-60.75+2.05*D+3708.6/D-13268/D^2	.48	22.4
Combined	-43.8+1.86*D+3401.7/D-11884.4/D^2	.43	22.5
Dollars per thousand lumber tally:			
Grade 1	763.7+0.1*D^2	.13	17.2
Grade 2	1616.5-30997/D	.47	26.4
Grade 3	126.7+16.5*D	.40	25.0
Grade 5	54.8+14.54*D	.67	24.8
With frost cracks graded as grade 5 logs:			
Grade 1	634.9+7.56*D	.12	14.7
Grade 2	222.9+15.7*D	.40	17.9
Grade 3	212.28+14.43*D	.35	23.0
Grade 5	54.7+14.3*D	.63	26.3
Dollars per thousand net log scale:			
Grade 1	1017.95		
Grade 2	1205.1-466828.8/D^2	.27	32.4
Grade 3	390.7+9.9*D	.14	28.6
Grade 5	287.4+8.5*D	.28	27.8
With frost cracks graded as grade 5 logs:			
Grade 1	1017.95		
Grade 2	439.0+12.0*D	.13	26.2
Grade 3	486.2+7.6*D	.09	27.5
Grade 5	287.3+8.3*D	.25	29.0

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Utilization standards and measurement systems have changed since the first lumber recovery study was conducted on sugar pine in 1957. These changes prompted a new study to provide new information on lumber volume and value recovery and a comparison to older studies. Lumber volume and value recovery are presented for the recent study on a board- and cubic-foot bases. Comparison to older studies showed that both volume and value increased over time because of improvements in technology, quality control methods, drying techniques; increased premiums for high grade clear material; and scarcity of the high grade resource.

Keywords: Sugar pine, *Pinus lambertiana*, lumber, California, board feet, cubic feet.

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